A Superposed Quantum Model of Brain Spiking Neurons

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Abstract

in all mammalian brain billions of neurons exist and these neurons are working together through synapses and spike responses. A big question stand still in the field of neuroscience. Why a neuron can produce different types of spikes under same conditions? We showed that unknown and random behavior of neuronal spikes through time can be described by this quantum fact that a neuron can be in many states at a same time, therefore any spike patterns or combination of spike patterns can be understandable. Based on neuronal spikes patterns, sometimes we observed an unknown pattern can be explained by this phenomena that a neuron can exist partially in a physical state but when it's response to an stimuli is recorded the result would be only one of the possible states or a linear combination of some states.

Introduction

To investigate those spiking patterns which are not fully described by previous models we proposed a two dimensional ordinary differential equation (ODE) model based on Izhikevich model [12]. Due to hyperbolic nature of results of differential equations we built up our model based on a hyperbolic function that can generate all bursting patterns of a neuron along with most of different types of spikes. We show how our model can also address some issues regarding abnormal neuronal responses via considering the quantum superposition fact. Quantum superposition clarifies a phenomena in which a particle can exist in many states simultaneously but while observing it will be only a particular state [15], [16].based on linearity of Schrodinger equation [17] any results that satisfy the equation can be also used in a linear format as a new result. Therefore we can say that abnormal patterns of neuronal spike can be considered as a results of neuron being in a superposition system, hence it can be consisted of all possible spikes as different states at the same time while when we measure the response it will show one of the states or as we call one of the patterns.

Proposed Model

Many neuronal patterns can be considered as a superposition of a neuron being in different states.

$$C_0|0> +C_1|1> + \cdots + C_n|n>$$

As shown in figure 1 if we consider a single cell in brain as a quantum superposed system, we can clearly define how this cell can generate different spiking patterns (quantum states) .

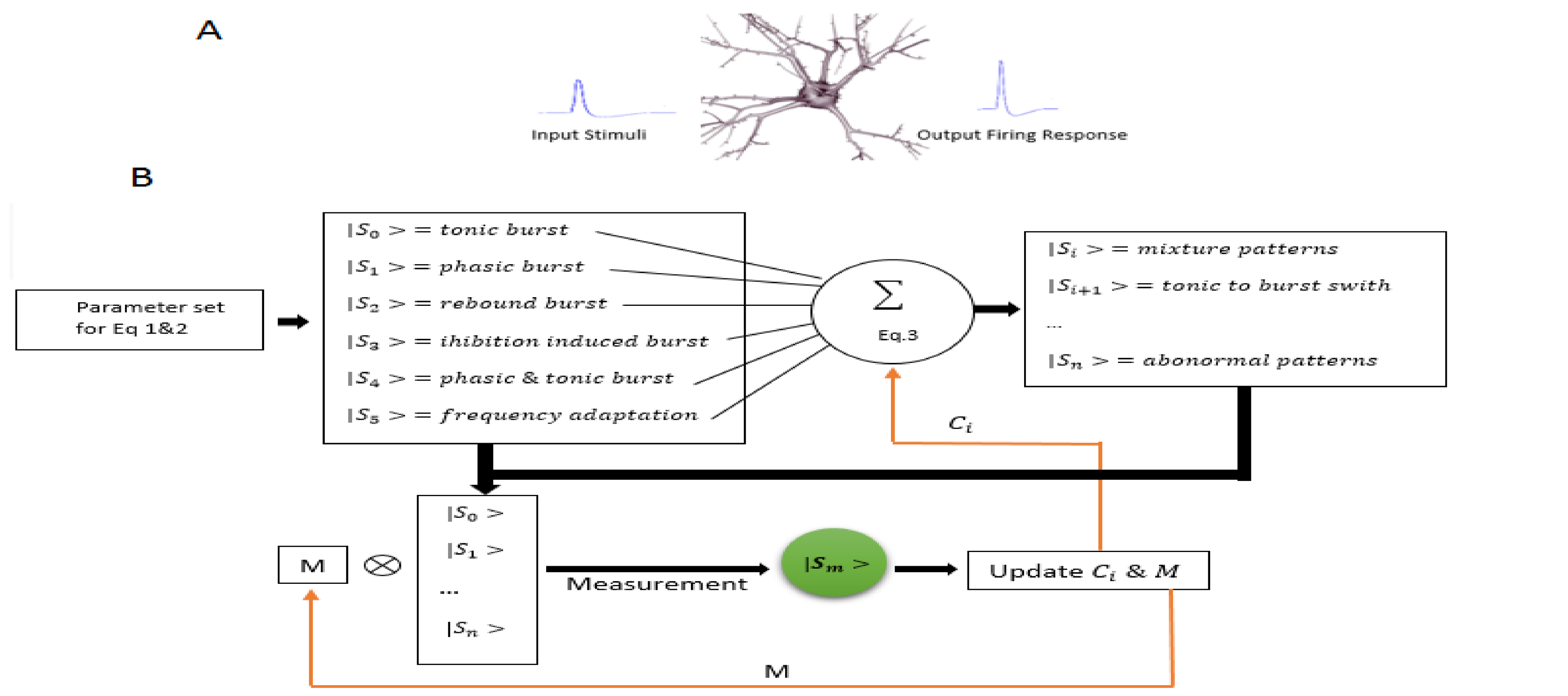

Fig. 1. A. schematic of a neuron: under input stimuli it will generate an spiking pattern as an output. B. modeling this neuron in a quantum superposed system with the ability of generating unknown and abnormal patterns. Through measurement a state called S_m would be obtainable which is same as our six primary states. Then we should update M and C_i for the next measurement in order to create our desired patterns.

Suppose we want to create this pattern through our system . Steps below show how this task should be done:

I. Generate two different firing patterns based on equation 1 & 2 $|S_0>$ = single spikes and $|S_1>$ =burst spike, which are presenters of our two primary states.
II. Based on actual recordings of our desires STN neurons we can create a vector of possibilities $[C_0, C_1]$ which shows in a STN neuron how often we can see single spike or bursting patterns with respect to vector of possibilities [34].
III. Generate the superposed state $|S_2> = C_0|S_0> + C_1|S_1>$
IV. For a time period T_0, weight M in order to choose $|S_2>$ (after measurement we will get either state $|S_0>$ or state $|S_1>$ based on the probability of C_0 or C_1.
V. Update M and C vector so we can measure state $|S_0>$ or state $|S_1>$ while selecting $|S_2>$ for time period of T_1.
VI. Our measurement for time interval T equal to $T_0 + T_1$ gives an abnormal pattern of single spike switching to burst mode of STN neurons in Parkinson's disease.

Simulated Results and Discussion

Based on our proposed system in figure 1 we generate the single to burst switching pattern as follows: first of all we set the parameters of our model in equation 1 & 2, in order to get 14 different kinds of spikes. We put these spikes as 14 different states of our system named S_0 to S_{13} . Then we generated some mixture patterns such as single to burst switching mode and set these new patterns (states) and our 14 primary states in a whole new matrix of states. For any desired pattern we adjust matrix M somehow to select that specific state, which in our case would be single to burst spike S_{14}. According to superposition theory whenever we measure the output of system, most likely it will give us the state which has a higher probability (c_i). Therefore when we want to measure S_{14} it will give us either S_0 which is single spike or S_1 which is burst pattern according to c_0 and c_1. Using Matlab we simulated this system for obtaining the sub thalamic nucleus neuronal responses which can be compared with real recording results (figure2).

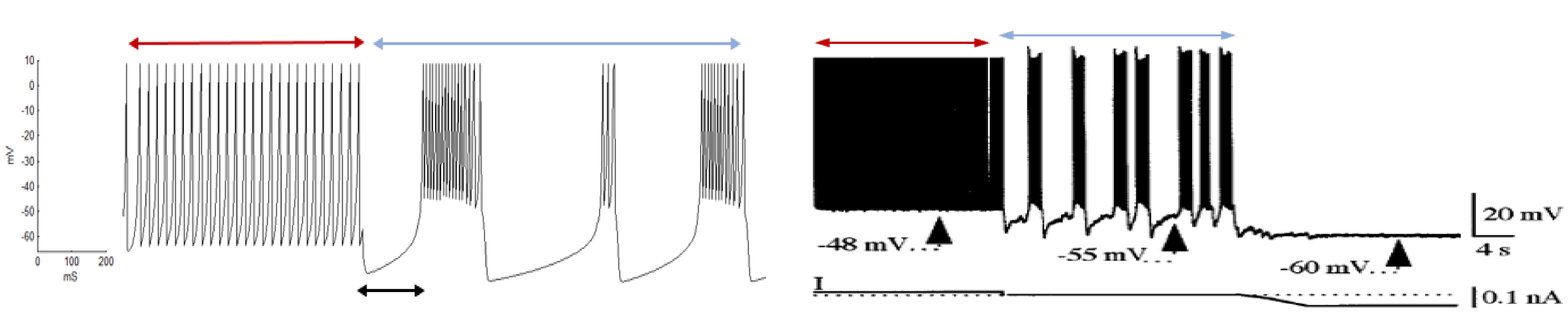

Fig. 2. single spike to burst switching pattern. single spikes happen in the red area while bursting spikes are shown in blue area .our model simulated results (right), actual recording of Sub thalamic nucleus neurons (Left)